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6 October 2003

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Acknowledgments:

The research project is funded partly by grants from the Austrian Central Bank, OeNB, (No. 9706) and from the Kaerntner Wirtschaftsfoerderungsfonds.

Abstract: The main goal of this paper is to provide a key metrics system for variety steering in mass customization. We distinguish between objective and subjective customer needs. The subjective needs are the individually realized and articulated requirements, whereas the objective needs are the real ones perceived by a fictive neutral perspective. We show that variety in mass customization has to be orientated on the objective needs. In order to help mass customizers better evaluate the degree to which they can fulfill the objective needs as well as their internal complexity level, we have developed a key metrics system model. We also present a conceptual application showing how to use this model to support decision making related to the introduction or reduction of product variants.

Blecker, Th./Abdelkafi, N./Kaluza, B./Friedrich, G.: Key Metrics System for Variety Steering in Mass Customization,
in: Piller, F. T./Reichwald, R./Tseng, M. (Ed.): Competitive Advantage Trough Customer Interaction:
Leading Mass Customization and Personalization from the Emerging State to a Mainstream Business Model.
Proceedings of the 2nd Interdisciplinary World Congress on Mass Customization and Personalization - MCPC'03,
Munich, October 6-8, 2003, S. 1 - 27

1 Introduction

With the development of mass production techniques, it is becoming more and more possible to provide products at low costs that can also be affordable to consumers with low incomes (Pine, 1993). These standard products are market-focused and only contribute to the average satisfaction of some customers. The mass production model successfully implemented by many firms is suitable in a static business environment, in which demand dominates supply. But the business environment has changed and is now characterized by high dynamics where technology continuously evolves and customers are more demanding. In order to improve their competitive position, manufacturers provide different products to different segments of the market. The segmentation reaches the level of individuals and "markets of one" arise. Customers also demand individualized products (not at any price but) at affordable prices. Mass customization (Davis, 1987; Pine, 1993) is a strategy that tries to fulfill the individual needs of the customers and which links two concepts, which at first glance, seem to be opposites, namely customization and mass production.

The goal of mass customization is to offer customer-focused products with a large degree of individuality, so "...that nearly everyone finds exactly what they want" (Pine, 1993). As a result, a batch size of one is conceivable in mass customization meaning that product variety can be very high, also causing a high complexity in operations and process. Two types of variety can be observed, namely the external and internal varieties. While the former is seen by customers and often but not always good, the latter which is experienced inside manufacturing and distribution operations, is always bad (Anderson, 1997). A mass customizer has to efficiently manage this variety, in order to avoid a variety explosion, which is associated with high costs (Knolmayer, 1999).

Mass customization disposes of a great potential to decrease costs by reducing finished goods inventories and avoiding special offers. The customer-pull system in mass customization especially improves the planning process in dynamic markets. Finished goods are only produced when a customer order arrives. Customer integration and interaction are also considered to be additional decreasing cost factors (Rogoll/Piller, 2002). On the other side, variety-driven complexity arises. Knolmayer (1999) points out that variety leads to decision-making difficulties for customers as well as to logistic, after-sales and documentation problems. Complexity triggers additional costs (Rosenberg, 2002), which must be reduced to the minimum and permanently kept under the benefit level resulting from pursuing the mass customization strategy.

Companies pursuing mass customization often believe that offering large number of product alternatives is positively perceived by the customers. But customers do not honor individualization per se. They only want to have the product that suits their requirements. They accept a price premium for customized products only when they believe they are getting an additional benefit from it (Piller/Ihl, 2002). Therefore, it is necessary to gear the product variety towards the customers' real needs. In this paper, we will briefly explain the variety problems in mass customization. We will also provide a model showing that the origin of the variety problem is the misconception of real customer needs. Furthermore, we will show that the existing variety steering concepts are insufficient in the case of mass customization. In order to provide a solution to the variety steering problem in mass customization, we have developed a comprehensive key metrics system concept. This system is derived from an analysis of the important subprocesses in mass customization. Then we will discuss the requirements as well as the constraints of the elaborated key metrics system.

2 Variety Problems and Shortcomings of the Existing Variety Steering Concepts in Mass Customization

2.1 Variety Problems in Mass Customization

Many examples of the implementation of mass customization show that variety creation decisions in mass customization are not well-founded. E.g. Cmax.com, a mass customizer of sport shoes offers approximately $3*10^{21}$ variants on the Internet. The entire surface of the earth would scarcely suffice for exhibiting all the possible variants (Piller et al., 2003). Many other examples from the automobile industry also show that the theoretical possibility of the number of variants the customers have to choose from is by far larger than what the customers actually perceive and buy. Therefore, in mass customization it seems that variety offer is generally oriented on what the company is able to do in terms of manufacturing but reflects in no way good customer orientation.

Anderson (1997) defines two categories of external product variety. The first category is useful variety, which is appreciated by the customers and contributes to their satisfaction. The second category is useless variety, which is transparent and causes bad effects such as customer confusion. The challenge the mass customizer has to face is to offer only useful variety often honored by customers. Moreover, the large number of variety possible in mass customization is associated with high costs. An empirical study of Wildemann (2001) has shown that with the doubling of the number of product variants, the unit costs would increase about 20-35% for firms with traditional manufacturing systems. For segmented and flexible automated plants the unit costs would increase about 10-15%. Wildemann concluded that an increase of product variety is associated with an inverted learning curve.

The problem of increased unit costs because of large variety is principally due to the additional complexity the mass customizer has to cope with. Complexity is defined as the interplay of three main dimensions: variety, connectedness and uncertainty (e.g. Ulrich/Probst, 1988; Schmidt, 1992). Reposing on this definition, the product assortment in mass customization appears as a very complex system because of:

- High variety due to the high number of end variants.
- Connectedness referring to the different linkages and interactions existing between the assortment elements (product variants).
- Uncertainty, which is induced by the continuous evolution of customer needs often making it very difficult in mass customization to exactly determine the optimal state the product assortment should take at a given point in time.

Furthermore, the complexity of the product assortment increases the complexity of the manufacturing process. Complex routings as well as frequent changeovers on the shop floor are often the consequence. The main important task of the production logistics is to master the complexity of manufacturing planning, scheduling and control in order to provide a high delivery performance (e.g. Lingnau, 1994).

Recapitulating, we can say that variety triggers high complexity in mass customization. We distinguish between internal and external complexity. The internal complexity is due to high variety as well as to complex process structures and flows in mass customization. The external complexity is due to the fact that the customers are confused when they face a high product variety. Product modularization is in fact considered as an enabler for mass customization because it enables the production of customized products while profiting from both economies of scale and economies of scope. Mass customization became possible owing to the advances realized in this field (Pine, 1993). But it is a huge error to believe that a large variety will contribute to high individualization and consequently to high customer satisfaction. In the following section, we propose a model to enable better understanding of the variety problem arising in mass customization.

2.2 Impacts of the Differentiation between the Objective and Subjective Customer Needs

In the technical literature, the most often cited factors which drive variety are customer orientation and variety regardless of the development of new products (e.g.: Lingnau, 1994; Anderson, 1997). In addition to these factors, we consider the misconception of customer needs as the basic cause for increasing variety in mass customization. We distinguish between objective and subjective customer needs. The subjective customer needs are the individually realized and articulated requirements, whereas the objective needs are the real ones perceived by a fictive neutral perspective. Using knowledge management terms, the subjective needs are explicit, while the objective needs are implicit. The existing discrepancies between the objective customer needs, the subjective customer needs and the offered variety are due to the following reasons:

- *The customers do not know their real needs*.

  Mass customized products are not just products for experts, who know exactly the configuration they want to have. Mass customization rather addresses a wide range of customers which goes by far beyond the scope of experts. For the non-expert consumers, it is often not a simple task to express their own preferences. One can simply imagine the process the home-owner goes through when designing a customized kitchen (Kahn, 1998).

- *The customers cannot express their real needs correctly*.

  Even if the customers know their real needs, they may have problems to communicate them to others properly. Because the majority of customers are non-expert consumers, they will not use technical parameters to describe their needs, rather, they will use verbal language in terms of verbs and adjectives or body language such as gestures or a system of symbols such as pictures and signs. Furthermore, there are some aspects like feelings and emotions, which are hard to explicitly express.

- *The mass customizer wrongly interprets customer requirements*.

  In order to explain this aspect we use the levels of semiotics' concept. Three levels of information transmission exist between a sender and a receiver. The first level is the syntactic level and deals with the transmission of signs. The semantic level builds upon the first level and considers an additional aspect related to the meaning of signs. The third level is the pragmatic level including, in addition to the transmission and meaning of signs, the intention of the sender (Reichwald, 1993). By applying this model to our case, we conclude that a disturbance at one of these three levels will lead to a communication problem between the mass customizer and the customer, triggering further discrepancies between the different types of needs and the offered variety. For example, at the pragmatic level the mass customizer can consider an important message of the customer as not relevant.

The model of Figure 1 visualizes the existing discrepancies between the subjective, the objective customer needs and the offered variety. The circle representing the variety offer of the competitors points out that the decision of adding new variants in mass customization has to take into consideration not only the company and customer perspectives, but also the competitors' perspective. The new product variants to be added to the production program should be competitive with similar variants of the competitors. Therefore, the relative cost position should be carefully examined by the mass customizer.

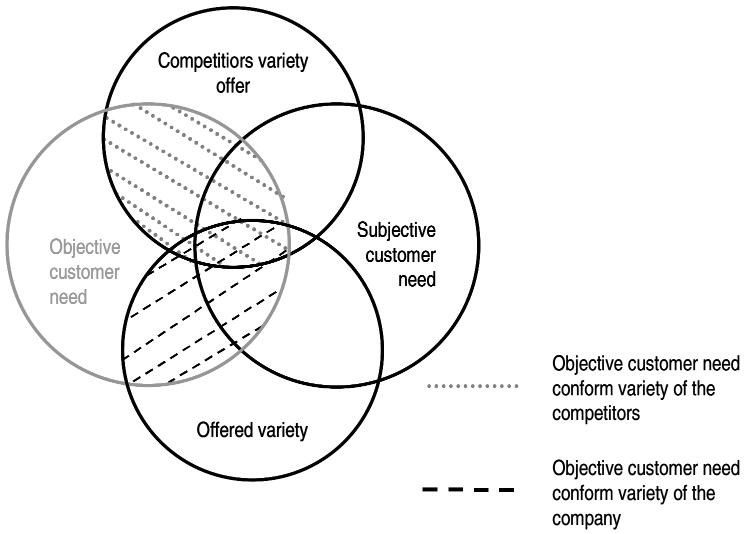


Figure 1: Customers' objective and subjective needs in mass customization

From the model we can conclude that in order to optimize variety, the mass customizer has to orient development and rationalization efforts toward the objective customer needs and in no way toward the subjective needs. The subjective needs lead to variants, which confuse the customers and present only sub-optimal customer satisfaction. They may also cause higher complexity costs rather than benefits for the mass customizer. However, the subjective need is the expressed one and is relatively easy to detect by means of several methods such as customer interviews or conjoint analysis. Jugel (2003) confirms the deficiencies of these methods and points out that a customer needs analysis often results in customers actually preferring another product other than what they themselves believe. Ulrich and Eppinger propose a method to help avoid, in part, the communication problems that can arise when customers express themselves. "Watching customers use an existing product or perform a task for which a new product is intended can reveal important details about customer needs" (Ulrich/Eppinger, 2000, p. 63). The challenge for the company consists in being able to draw the boundaries of each type of need and to determine which variants are over-engineered, which ones are corresponding to the subjective needs and which ones are fulfilling the objective needs of customers. From the differentiation between objective and subjective needs, we derive the first thesis of the paper:

Thesis 1: *A mass customizer has to evaluate and fulfill objective customer needs in order to reach optimal customer satisfaction and strategic success.*

2.3 Insufficiencies of Existing Variety Steering Concepts

By applying the model which distinguishes between the objective and subjective customer needs, we will explain the shortcomings of the existing variety steering concepts for mass customization. At first it is important to make the distinction between variety management and variety steering. Variety management embraces all the concepts that can be applied in order to increase component and process commonality levels during a company's operations. The main goal of these concepts is also to master the operation complexity and profit from the advantages of both economies of scale and scope when producing variety. As examples for variety management concepts we can cite strategies like part families, non-variable parts, building blocks, modular product architectures and platform (Wildemann, 2003). Unlike variety management concepts, which mainly concentrate on an internal variety perspective, variety steering concepts essentially deal with external variety, which is apparent to the customers. The variety steering concepts or tools frequently addressed in the literature are Pareto analysis, contribution margin accounting and activity-based-costing.

- *Pareto analysis*

  Pareto analysis seeks to discover which variants are unimportant and transparent to customers. With the help of a Pareto analysis, Nissan automobiles found out that from the 87 existing steering wheels available, around 17 types accounted for 95% of the total installed (Anderson, 1997). The 70 steering wheels, which only account for 5% should be considered as candidates for eventual elimination.

- *Contribution margin accounting method*

  The first step of this method is to examine the contribution margins of both customers and end product variants with the help of an ABC-Analysis. The second step aims at representing both results of the first step in a product/customer-based portfolio. The critical product/customer combinations issue of this analysis, namely BC and CC combinations will be carefully examined for elimination from the production program (Wildemann, 2000).

- *Activity-based-costing*

  The goal of activity-based costing is to fairly allocate the complexity costs arising in terms of indirect costs to the different product variants. So it is possible to provide a more or less accurate cost calculation for the different product variants. Based on the results of this method, the variants presenting high costs that are not honored by the customers are selected for an eventual elimination (e.g. Braun, 1999).

Pareto analysis is past-oriented and assumes that variants, which haven't until now been perceived by customers, have to be eliminated if there are no further constraints such as e.g. delivery commitment. Moreover, though the contribution margin accounting method considers two important perspectives of customers and end product variants, it is also based on a classification of contribution margins according to an ABC-analysis. Further**,** the computation of contribution margins of end product variants seems to be suitable for serial or mass production but not for mass customization assuming a batch size of one. Even if contribution margins can be accurately computed, the analysis may lead to the elimination of single variants consisting of some components or modules being important for the manufacturing of other retained product variants. So the full potential of the method cannot be tapped in mass customization. Moreover, activity-based-costing certainly has a great potential to compute variety costs but this method is generally associated with high costs, if accurate results have to be attained. The challenge is to be able to balance the costs needed for the method itself and the savings that would result from the implementation of the method.

Assuming that a mass customizer intends to rationalize the production program on the base of a Pareto analysis, this will simply lead to the elimination of the product variants customers have not perceived. Between these variants, there may be some variants corresponding to the objective needs of some customers. Even though these variants would generate optimal customer satisfaction, they could be eliminated. Thus, the basis of the decision saying, in this case, that all variants that are not recognized by customers can be selected for eventual elimination seems to be insufficient. Moreover, we do not agree that these concepts only aim at reducing the size of the product assortment. We consider that an efficient concept for variety steering must be able to simultaneously eliminate useless variety and generate useful variety based on the objective customer needs. So we derive the second thesis of the paper:

Thesis 2: *Existing variety steering concepts are not sufficient for an efficient variety steering in mass customization.*

As previously mentioned, an accurate computation of complexity costs by implementing, for example, the activity-based-costing method can be very cost-intensive. To ensure that the intended variety steering approach on the one hand provides reliable results for mass customizers and, on the other hand, does not excessively require available resources, we opt for a key metrics system model. Steering variety by means of simple metrics based on existing data in the company is not cost-intensive and easy to carry out. To determine the most important key metrics we define firstly the sub-processes that are crucial in a mass customization system. The sub-process analysis is advantageous because:

- it is comprehensive and encloses all the variety driving activities;
- it provides an efficient methodology to structure the variety problem;
- it shows that decisions related to variety at one sub-process level influence the performance of other sub-processes.

Thus, the third thesis of this paper is:

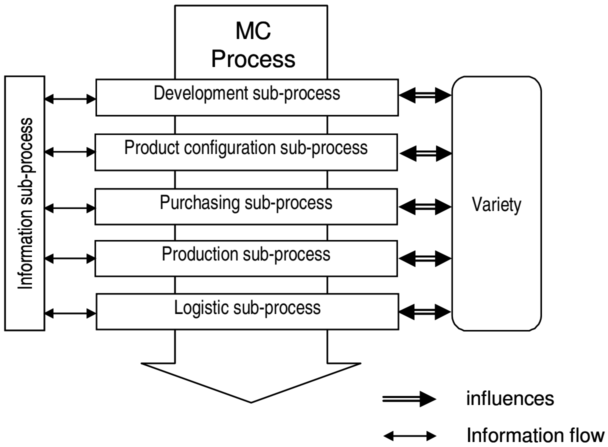
Thesis 3: *An efficient variety steering concept has to be based on a key metrics system enclosing all relevant sub-processes.*

3 Development of a Key Metrics System for Variety Steering in Mass Customization

3.1 Definition of a Sub-process Model

In the literature related to mass customization, it is not explicitly mentioned what the critical sub-processes are for mass customization systems. Instead, Zipkin (2001) discusses three key capabilities of mass customization, which are elicitation, process flexibility and logistics. The elicitation process often supported by enabling mechanisms is basically defined as the process customers go through to identify what they want. Process flexibility mainly relates to the required capabilities by the production systems like short-time changeovers on the shop floor. A great importance is also attached to production and distribution logistics and also to the information required for a smooth flow of both operations. Furthermore, the scope of a research project at the University of Oxford, UK completed in July 2003, Mchunu et al. (2003) points out that there are five competencies with specific relevance for mass customization which are design, flexibility, supply chain agility, distribution of inventory and logistics and information management. We notice that the key capabilities defined by Zipkin as well as the competencies discussed by Mchunu et al. relate to main sub-processes in mass customization.

Based on this previous work, we have defined a sub-process model for mass customization consisting of six main sub-processes, namely the development sub-process, the product configuration sub-process, the purchasing sub-process, the production sub-process, the logistic sub-process and the information sub-process (Blecker et al. 2003). Figure 2 presents all these sub-processes and their interrelations with variety.



Source: Blecker et al., 2003, p. 9

Figure 2: Relevant sub-processes in a mass customization system

In the following we briefly describe the identified sub-processes in mass customization. We also show their relevance for the implementation success of the strategy.

- *Development sub-process*

  During the development process, 80 percent of the lifetime cumulative cost is generally determined. In a mass customization system product architecture determines 60 percent of a product's cost and constitutes a high leverage opportunity for reducing costs. Furthermore, to ensure mass customization efficiency, customer needs should be mapped to a product family instead of a single product (Anderson, 1997). Main concern is to develop product architectures based on common parts and components and at the same time capable of generating a wide customer oriented-variety.

- *Product configuration sub-process*

  Product configuration is the first step in the value chain of mass customization (Piller, 2001). It constitutes the interaction between producer and customer and determines to a great extent the success or failure of the total customization process. With the help of web-based configuration tools, customers can carry out self-configurations. The software tools used should be easy to operate and have to facilitate the search process for the customers. Riemer/Totz (2001) argue that the total customer satisfaction level depends not only on the quality of the end product but also on the quality and easiness of the configuration process.

- *Purchasing sub-process*

  The purchasing process can be negatively affected by the variety-driven complexity which arises in a mass customization system. A large variety of suppliers and purchasing sub-processes is often hard to manage and trigger cost disadvantages. To optimize the purchasing process, Wildemann (2000) proposes to cluster the material groups using an ABC-analysis. For example, for B and C material groups, it is advantageous to opt for a few typical purchasing processes. There are also many concepts frequently discussed in the literature and successfully implemented in the practice like supplier integration, modular or single sourcing that offer great potential for decreasing complexity in purchasing.

- *Production sub-process*

  The production sub-process in mass customization presents a decoupling point separating both mass production and customization processes. Delaying the decoupling point towards the end of the value chain considerably decreases the manufacturing complexity (e.g. Wildemann, 2000; Wildemann, 2003). Furthermore, the production sub-process in mass customization should dispose of three main capabilities which are flexibility, agility and efficiency. Flexibility basically reflects the capability of managing any mix of orders and thus producing a large number of variants in little batches with few processes. Agility deals with rapid system responsiveness to unforeseen customer requirements (Goldman et al., 1995). Efficiency mainly concentrates on cost considerations.

- *Logistic sub-process*

  The logistic sub-process is critical to the success of mass customization and can offer additional individualization opportunities like individualized packages or delivery times (Riemer/Totz, 2001). To evaluate the performance of the logistic sub-process two main parameters should be taken into consideration, namely, delivery reliability and work-in-process inventory level. The implementation of the just-in-time concept leads to a significant improvement of both parameters and contributes to the attainment of cost advantages.

- *Information sub-process*

  The information system should provide the information needed for the smooth flow of all the above described sub-processes. In addition, the information sub-process in a mass customization system has to be organized in such a way that no information breaks arise (Rogoll/Piller, 2002). Therefore, certain organizational and technical capabilities have to be provided. An efficiently integrated information system for mass customizers should capture customer product configuration, develop a list of product requirements necessary to achieve the order, determine specifications of manufacturing as regards the customer configuration, set up the manufacturing system, arrange for end product shipment and enable the verification of a product's order status (Berman, 2002).

A further decomposition of the sub-processes will not be carried out because we want to keep our sub-process model as general as possible. The goal of the above mentioned analysis is to determine the relevant key metrics capable of supporting variety steering decisions in mass customization.

3.2 Sub-Processes-Based Key Metrics System for Mass Customization

Key metrics are quantitative measurements that give useful information related to measurable facts through aggregation and relativization. They are generally used in operational controlling and serve to control success potentials (Reichmann, 2001). Moreover, key metrics can be either used as information or steering instruments. Typical key metrics deployed for information purposes are those delivered by annual accounts. They describe the development of the company in the past and enable the appreciation of business trends. Steering key metrics are used in connection with predefined goals and indicate to what extent these goals are reached (Kuepper, 2001).

To identify the nature of the key metrics to be determined, we have to first explain how the key metrics should contribute to support variety steering. We assume that the mass customizer has already implemented a variety management concept consisting of a mixture of many strategies such as a platform strategy, modular product architecture, part families, etc. Variety steering does not strive towards, for example, increasing the modularity level or improving the product platform. Variety steering only relates to the decisions concerning the introduction or elimination of the end product variety provided to customers. But these decisions often affect the sub-process complexity.

Therefore, the key metrics for variety steering should capture the impacts of such decisions on the performance level of each sub-process. Moreover, the already implemented variety management concepts could restrict the decisions on variety steering. For example, if the product platform does not foresee the manufacturing of certain product variants, then the introduction of these variants to the production program would be impossible without eventual modifications or extensions of the product platform. That is why we can conclude that variety steering decisions can initiate some changes at the variety management level by modifying, for example, an existing product platform. However, the sub-processes-based key metrics are not able to deal with the problems resulting from the distinction between the objective and subjective customer needs. That is why we intend to extend the key metrics system in the next section.

Our main intention is to provide a key metrics system which can be simply installed in mass customization and which does not presuppose that the company has already developed such systems enabling them to compute complexity costs like, for example, activity-based costing. In order to determine a comprehensive key metrics system, selective literature research is necessary. The goal is not to provide a list of all sorts of possible key metrics, but to restrict them to the most significant ones, which can support variety steering decisions. That is why for each sub-process it is necessary to firstly carry out an examination as to which performance aspects will be influenced by or will affect variety decisions. Then, key metrics will be assigned to these performance aspects. Furthermore, the selected key metrics should be computed on the basis of data already available in the company.

In the literature there are many studies illustrating the influences of product variety on the *production sub-process*. Rathnow (1993) speaks about "diseconomies of scope" due to the variety-driven complexity and points out their negative effects on unit costs. Thonemann/Bradley (2002) examine the relationship between product variety and averages manufacturing lead times of a hard-drive manufacturer with six product lines. They found out that the average lead time for product lines with high product variety is greater than the average lead time for product lines with low product variety. This is primarily due to the frequent setups required for producing a large number of product variants on the same product assembly line.

However, the weight of setup times compared to the total manufacturing lead time depends on the type of the manufacturing process. Whereas in the automobile industry the changeover times between cars can be negligible as well, certain manufacturing processes including, for example, hard-disk manufacturing, metal stamping or circuit-board production are characterized by long setup times (Thonemann/Bradley, 2002). In order to guarantee a certain generality of our model, product changeovers, or setups will be retained as a parameter to be examined within the scope of variety steering decisions.

Anderson (2001) examines, on the basis of an empirical study including three textile manufacturing plants, the direct and indirect effects of product mix characteristics on capacity management decisions and operating performance. In contrast to previous studies which assume that capacity utilization and machine scheduling to be exogenous factors associated with market demand, Anderson empirically finds out that product mix characteristics explain to a large extent the variation of capacity utilization and machine setups. To mitigate this production planning and control complexity, it is important to prevent a great diversity of components and processes.

Therefore, variety steering decisions should not overlook the mass production perspective because mass customization essentially aims at satisfying individual needs while staying near mass production efficiency. To achieve the economies of scale, learning effects have to be maintained by using common processes and common components for the manufacturing of a large variety. Subsequently, in order to capture the impacts of variety steering decisions on the whole manufacturing process including both the mass production and the customization processes, evaluating the position of the differentiation point can be very helpful. The introduction of new product variants may displace the differentiation point towards the begin of the value chain triggering an earlier variety proliferation usually associated with higher complexity and costs. Whereas process commonality and the position of the differentiation point are parameters to assess the performance of the production sub-process, components commonality evaluates to some extent the quality of decisions made at the product development phase.

The performance at the production sub-process level considerably affects the performance of the *logistic sub-process*. The position of the differentiation point mainly influences the delivery performance and the work-in-progress inventory considered in our model to be the most important parameters to capture the impact of variety steering decisions on the logistic sub-process. Maskell (1991) points out that the “last-minute differentiation” provides more flexibility of production mix making it easier and quicker to respond to customer needs. Furthermore, a late differentiation point avoids the inventory risks arising from volume and variety risks. The success of Dell as mass customizer of computer hardware is essentially due to the combination of late differentiation point and postponement strategies. Dell has an inventory turnover of 7 days, whereas the competition must carry an inventory of 80 days or more. Especially in the computer industry, maintaining low inventory levels can be decisive for success because for every week inventory spends on the shelf, it loses one percent of its value (Murphy, 1999).

In addition to the production and logistic sub-processes, variety steering decisions also have great impacts on the *purchasing sub-process*. Wildemann (2000) cites the example of an automobile manufacturer and points out that five to ten percent of the total complexity costs arise in purchasing. Furthermore, Wildemann makes the distinction between the variety of purchased parts and the variety of purchasing processes. The variety of purchased parts essentially depends on the utilization level of platform and modules/systems-strategies. The variety of purchasing processes essentially results from the variety of suppliers and purchased parts as well as internal customers-suppliers-relationships. To capture the effects of variety steering decisions on the purchasing sub-process, we consider two parameters, namely purchasing process commonality and module suppliers weight. Whereas the first parameter indicates to what extent purchasing is based on the same processes, the module suppliers’ weight shows the importance of module suppliers compared to the total number of suppliers.

Considering the weight of module suppliers at the purchasing process level is due to the fact that we assume that the *development sub-process* in mass customization strives towards developing products on the basis of a modular architecture. We also consider that a product platform is a module with higher commonality degree compared to other product modules. Making this hypothesis when dealing with mass customization is allowed because “the best method for achieving mass customization...is by creating modular components that can be configured into a wide variety of end products” (Pine, 1993, p. 196). Ericsson/Erixon (1999) indicate that a properly used modularization has many advantages such as higher flexibility, reduction of product development lead time, parallel development of the product and production system, easier service and upgrading, reduced material and purchase costs. The product architecture has a direct influence on the component commonality. Good product architecture enables the satisfaction of the customer needs, while maximizing the commonality of parts and modules between product variants.

However, developing a modular product architecture capable of generating a large variety in mass customization does not mean that customers will have a survey of all possible configurations and that they are able to distinguish between all of them to make the optimal decision. As previously mentioned, many practical examples show that a majority of product configurations cannot be recognized by customers. That is why we have introduced a performance parameter for the *configuration sub-process* named “used variety” that compares the number of perceived variants to all those which are theoretically possible (Piller, 2002). So Cmax.com, the sports shoes manufacturer, would receive in this case a value of used variety which is too small due to the astronomic number of possible variants. Subsequently, we agree that the configuration systems over the web have a great potential to enable customers to recognize their own needs. Huffman/Kahn (1998) compared the attribute-based and the alternative-based presentations of product variants and concluded that customers can better discover their preferences thanks to an attribute-based presentation. Piller et al. (2003) point out that the experienced information overload due to large product assortments can lead to configuration processes that take a long time. The customers can feel an increasing uncertainty leading to the abortion of the configuration process. According to this, we consider the web appearance and the data format in the configuration sub-process as a decisive performance parameter for the variety presentation. By adding new variants, the mass customizer has to carefully examine whether the variety to be added will trigger increasing confusion and information overload for the customers. However, Kahn/Isen (1993) and Mitchell et al. (1995) point out that it is possible to encourage customers by seeking more variety. Inducing a positive mood while shopping by giving a gift to the customer, for example or pumping appropriate scents into the shopping environment can increase the customers’ desire for variety. These experiments are in fact carried out in a real environment, which is quite different from a virtual one over the Internet. The challenge in mass customization is how to adapt such findings to increase the variety seeking desire on the web by using configuration systems.

Furthermore, variety steering decisions affect the configuration system knowledge base consisting of the configuration database and the configuration logic because new variants have to be added and/or eliminated. The database should be updated as fast as possible in order to avoid such situations where the customer orders a product that is no longer available in the product assortment. Changes may also affect the configuration logic leading to modifications in the way the components or modules interact with each other (Rogoll/Piller, 2002). It is becoming more important that the configuration system leading to quick updates is easier to maintain when the frequency of variety changes tends to be high. Moreover, as already aforementioned, the integration level of the configuration system in the existing business processes is a relevant performance parameter to assess the capabilities of the *information sub-process* regarding variety steering decisions. Avoiding breaks in the information flow accelerates the speed of customer order processing, especially when the required documents for manufacturing such as routings and scheduling can be automatically and quickly generated. Assuming that the information flow presents many information breaks and that most documents have to be manually prepared, the variety increasing decisions can therefore accentuate this problem leading to long processing times. To evaluate the capabilities of the information system in mass customization, we consider two main parameters, namely, the integration level of the configuration system and its easiness of maintenance as well as the speed with which the required documents for manufacturing are prepared.

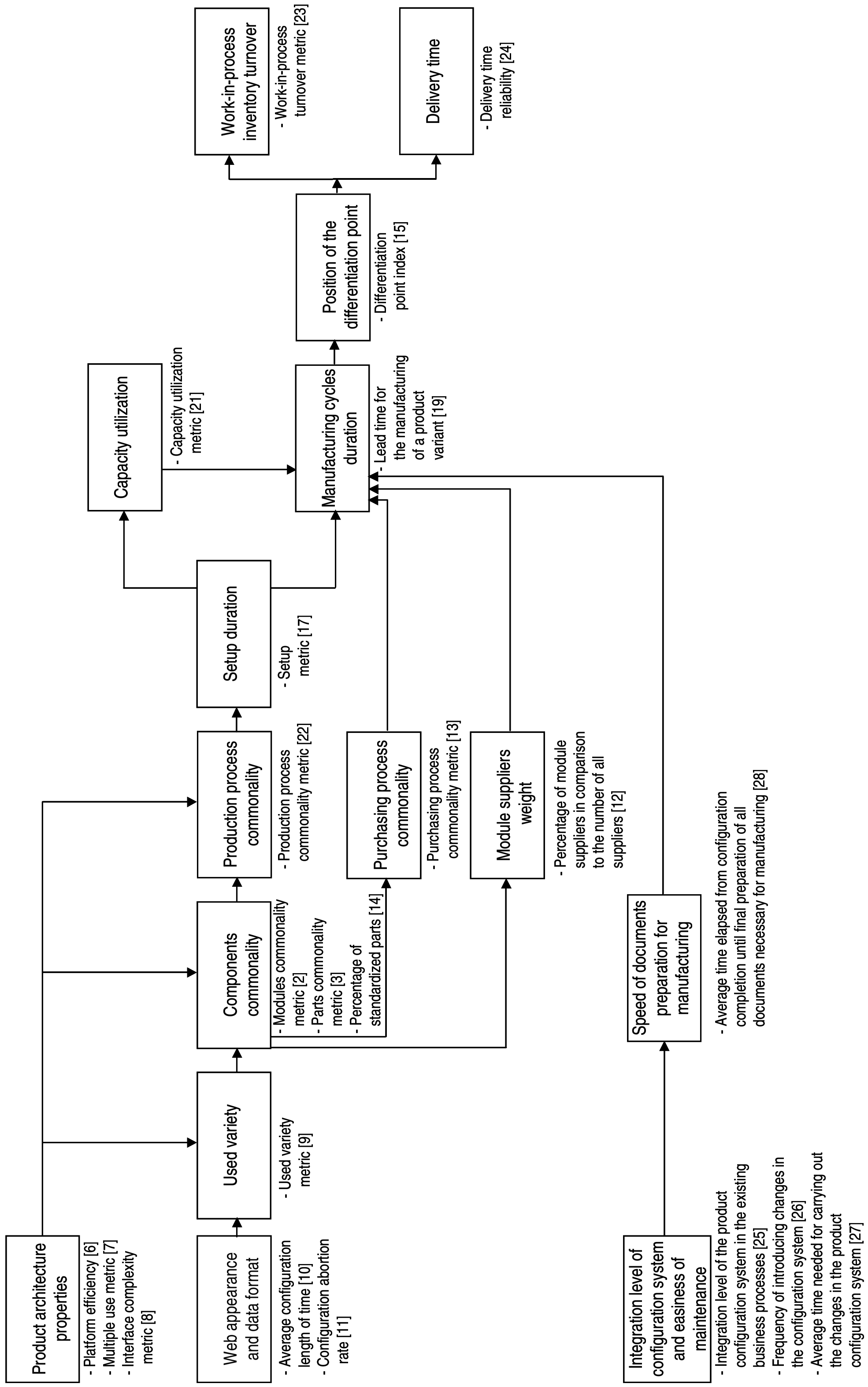


Figure 3: Sub-processes-based key metrics system for variety steering in mass customization

With the help of the sub-process analysis, we determine the performance parameters which are relevant to support variety steering decisions in mass customization. Due to the dependencies existing between the different sub-processes, it is comprehensible that there are also some interactions between the defined performance parameters.

For example, it is obvious that an early product differentiation will lead to a low degree of completion of mass produced components and modules. So in this case, the time needed for the manufacturing process is longer than when the differentiation occurs at a later point in the production process. An early differentiation point also increases the frequency of production disturbances and may lead to bad delivery reliability. So we can conclude that the position of the differentiation point has a direct effect on the delivery time. Moreover, we examine the interdependencies existing between all the performance parameters and we present them in a unique comprehensive model as shown by figure 3. The arrows point out the influence of the performance parameters on each other.

With this model, a better understanding of how the different sub-processes interrelate and how changes at one performance parameter affect the others is possible. We assign the corresponding key metrics to each of these performance parameters. A literature research is also carried out to determine the key metrics which are suitable to evaluate each of the performance parameters. But our research shows that in the basic literature, some key metrics needed for our model are not available, especially those required to evaluate the information and configuration sub-processes. To fill this gap we develop new metrics. For others metrics we agree that they should be improved in order to best suit our model. All key metrics are presented in the Appendix.

3.3 Extended Key Metrics System for Variety Steering in Mass Customization

The sub-process-based key metrics system explained above only deals with a company's internal perspective regarding variety steering. It does not enable the company to solve the problems that arise from customers' perspective when distinguishing between the objective and subjective needs. A better solution to this problem will be obtained when the intersection area between the circles representing the objective and the subjective needs and the offered variety is greater. Figure 4 shows that there are two directions the mass customizer has to consider in order to approach the customer objective needs. Direction (1) deals with how to help customers get to know their real needs better. A problematical situation arises when the customer believes that a variant (A) would fit his needs, but in fact there is another variant (B) in the product assortment that would better correspond to his requirements. Because the offered variety in mass customization is very large, the customer may not recognize variant (B) and chooses variant (A). The task of recognizing the real needs of the customers in a real shopping environment is generally carried out by advisors, who, due to their experience, are able to find the optimal choice for the customer. In a virtual environment over the web, we are convinced that the configuration system has a great potential to drive the customers towards the ideal variant while minimizing searching efforts.

But it is conceivable that the objective customer needs would be fulfilled by no variant in the product assortment. In this case even a good configuration system will not be able to lead the customers to make their optimal choice. Direction (2) indicates that the mass customizer has to continuously update the product assortment to approach the objective customer needs by reducing the over-engineered variants and those corresponding only to the subjective needs. In the following we describe some approaches capable of solving some of the encountered problems related to the differentiation between the objective and subjective needs. Then we extend the sub-processes-based key metrics system with customers' considerations.

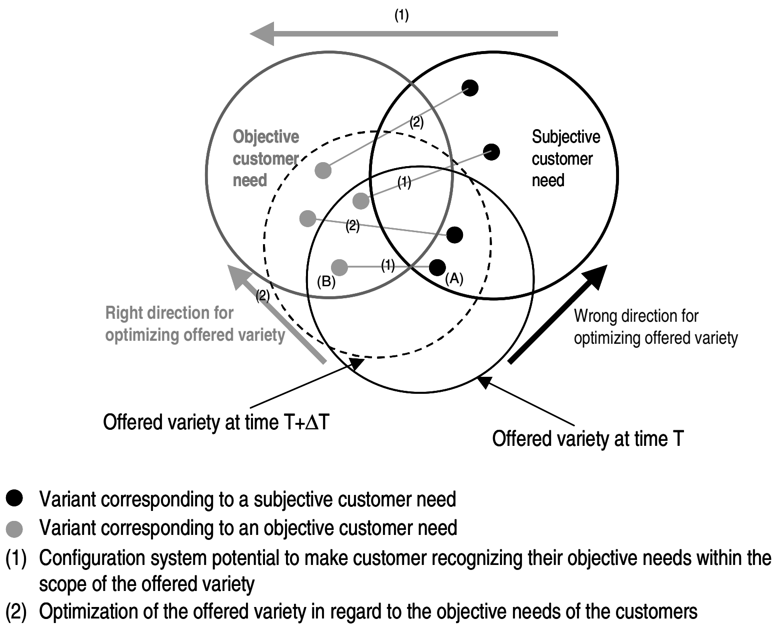


Figure 4: Variety optimization with regard to the objective and subjective customer needs

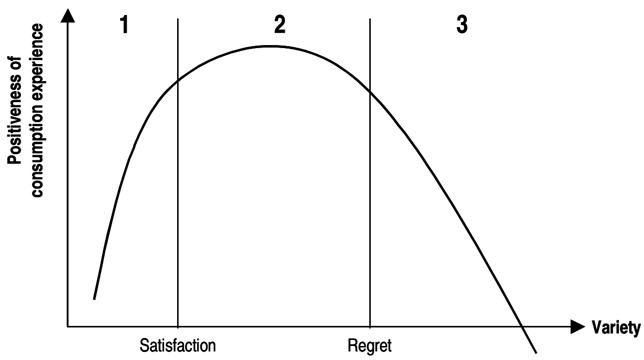
By using a module or part-oriented configuration system, customers can be overwhelmed by the amount of possible combinations. “The majority of people are able to say if they like a product (or a service). They are capable of choosing between houses, watches or car insurances. But being able to construct each of these things merely adding parts is not easy” (Porcar et al., 2001). However, the customers are generally not capable of comparing a large amount of end products because of the limited information processing capacity of humans. To help customers find adequate product variants the alternatives displayed should be restrained to a certain amount so that the customer can make an appropriate decision. A good configuration system would be capable of eliciting *real* customer needs (Ardissono et al. 2002), compare a large number of possible configurations already stored in the database and display only the product variants relevant to customers’ requirements. The effort needed to compare between different combinations will be lower. The customers should be also offered the chance to improve some product characteristics. A configuration system based on Kansei engineering is able to fulfill some of these aspects. Kansei engineering is a consumer-oriented technology for new product development and is defined as „translating technology of the consumer’s feeling and image for a product into design elements“ (Nagamachi, 1995, p.2). Using a Kansei engineering-based configuration system, customers can express their feelings on a product by entering personal and lifestyle data. Then the system can find the best-fit designs suitable to the requirements entered (see e.g. Nagamachi, 1995; Nagamachi, 2002; Prorcar et al., 2001) Thus, we can conclude that to mitigate customer confusion and help customers find the variants corresponding to their real needs, web appearance and data format should be supported by innovative solutions enabling an understanding of customer's needs, feelings, as well as what the customer intends to express through the customized product.

Kansei engineering is a solution approach to the problem arising when the customers cannot properly express their real needs (section 2.2). To deal with the problem when the mass customizer wrongly interprets customer requirements, we consider the key value attributes concept of MacCarthy et al. (2002). The main idea of this concept is that customers demand variety when they considerably differ in their preferences for certain product attributes. Customer preferences and values are relatively stable cognitions and beliefs (e.g. security, fun and enjoyment) and differ from one customer to another. Comparing these customer values involves value differences. The attributes of product configurations presenting high customer value differences are the key value attributes to be customized. The attributes with low value differences should be standardized. Variety steering concentrates in fact on the decisions made with respect to the customizable attributes. Therefore, the extended key metrics system should capture the impacts of such decisions by introducing a performance parameter called customizable attributes.

Kansei engineering and the key value attributes concept are approaches that enable some aspects of the communication problem between the customer and the mass customizer to be solved. However, dealing with the problem when the customers themselves do not know their real needs constitute a challenge that can only be partially solved using existing methods such as conjoint analysis, focus groups, lead users, etc. An empirical study carried out by Ekstroem/Klarsson (2001) shows that the involved companies were disappointed by the results of their customer interviews. The companies expected that their customers would be able to enumerate their needs using product specific terms. In contrast to the companies' expectations, customers were unable to formulate their requirements and did not propose innovative solutions. Thus, developing methods to elicit the real needs of customers when they themselves do not know their requirements is an issue for further research in mass customization.

From the previous analysis, we can conclude that web appearance and data format should be supported by an appropriate configuration system. Furthermore, a performance parameter related to the customizable attributes will be required for the extended key metrics system. However, the problem still remains as to which key metrics should be determined in order to evaluate whether variety steering decisions actually contribute to the fulfillment of the customer objective needs. The concept of Desmeules (2002) offers interesting approaches to solve this problem.

Desmeules (2002) examines the relationship existing between variety and consumer behavior. He proposes a graphical model showing how variety correlates with the positiveness of the consumption experience when the customers evaluate the product variants by cognition (Figure 5).



Source: Desmeules 2002, p. 10

Figure 5: Relationship between perceived variety and positiveness of consumption experiences when the evaluative task is performed by cognition

The "positiveness of a consumption experience" could be either customer happiness or satisfaction. Whereas customer satisfaction is a post-purchase evaluation of a product or a service, customer happiness extends the meaning of customer satisfaction to include also the shopping experience. Figure 5 shows three different sections. Section (1) indicates that adding new product configurations increases customer happiness because the likelihood that customers find the variant they are looking for is greater. Section (2) points out that variety does not have a great influence on the consumption experience and the corresponding variants may be either considered or ignored by customers. At the end of section (2) “point of regret”, customer happiness starts to considerably dive. In section (3), it is assumed that the variants added will cause more stress, frustration and regret to the customers. Regret arises because customers feel that they did not find the optimal solution and that another product configuration would be more suitable for them.

Based on this previous work, we can state that product variety situated after the point of regret will increase the probability that the customer makes a decision leading only to a sub-optimal satisfaction. This is in accordance with our definition of the variety corresponding to the subjective needs. Furthermore, we expect the likelihood that customers do configurate the product corresponding to their objective needs is greater when variety approaches the point of satisfaction. Thus, we propose to extend the key metrics system for variety steering with customer happiness considerations defined as the satisfaction of both the shopping experience and the product itself after purchase. For this reason, we define the performance parameters “potential customer happiness” and “customer happiness”. In mass customization, it is relevant to keep an eye not only on the customer who is defined as a “…visitor or a user who buys something” (Sterne, 2002, p. 164), but also on the potential customer who “…has the need, the desire, and the means to make a buy” (Sterne, 2002, p. 146). The potential customer happiness can be tracked with the percentage of new potential customers who show their interests in the product assortment. For the evaluation of customer happiness, we propose the key metrics churn rate, return rate and complaints rate. Because happy customers do more business and purchase more often, it is expected that customer happiness affects the performance parameter “repurchase rate”. Furthermore, it is interesting to evaluate to what extent the potential customer happiness affects the growth rate of the performance parameter “new customers base”. The repurchase rate as well as the new customer base will have an influence on the performance parameter “sales”.

The extended key metrics system for variety steering in mass customization is represented by figure 6. It shows the interrelations between all the performance parameters related to both considerations of sub-processes and customers. The key metrics which are assigned to each performance parameter should not be seen as definite metrics. The assignment has been done assuming a general case in mass customization. So it is conceivable that these key metrics can be adapted, other key metrics can be defined to fit a particular case. But we are convinced that the defined performance parameters and their interrelations suit the majority of cases in mass customization.

3.4 Key Metrics-Based Application for Variety Steering in Mass Customization

In order to explain how to use the key metrics system to support variety steering decisions we have developed a conceptual application. This application presupposes that we dispose of two hypothetical units capable of examining the existing product attributes, picking out and suggesting critical ones. The first unit (O) recognizes the product attributes contributing to the objective customer needs. The preferences related to these attributes are very different from one customer to another and present high value differences.

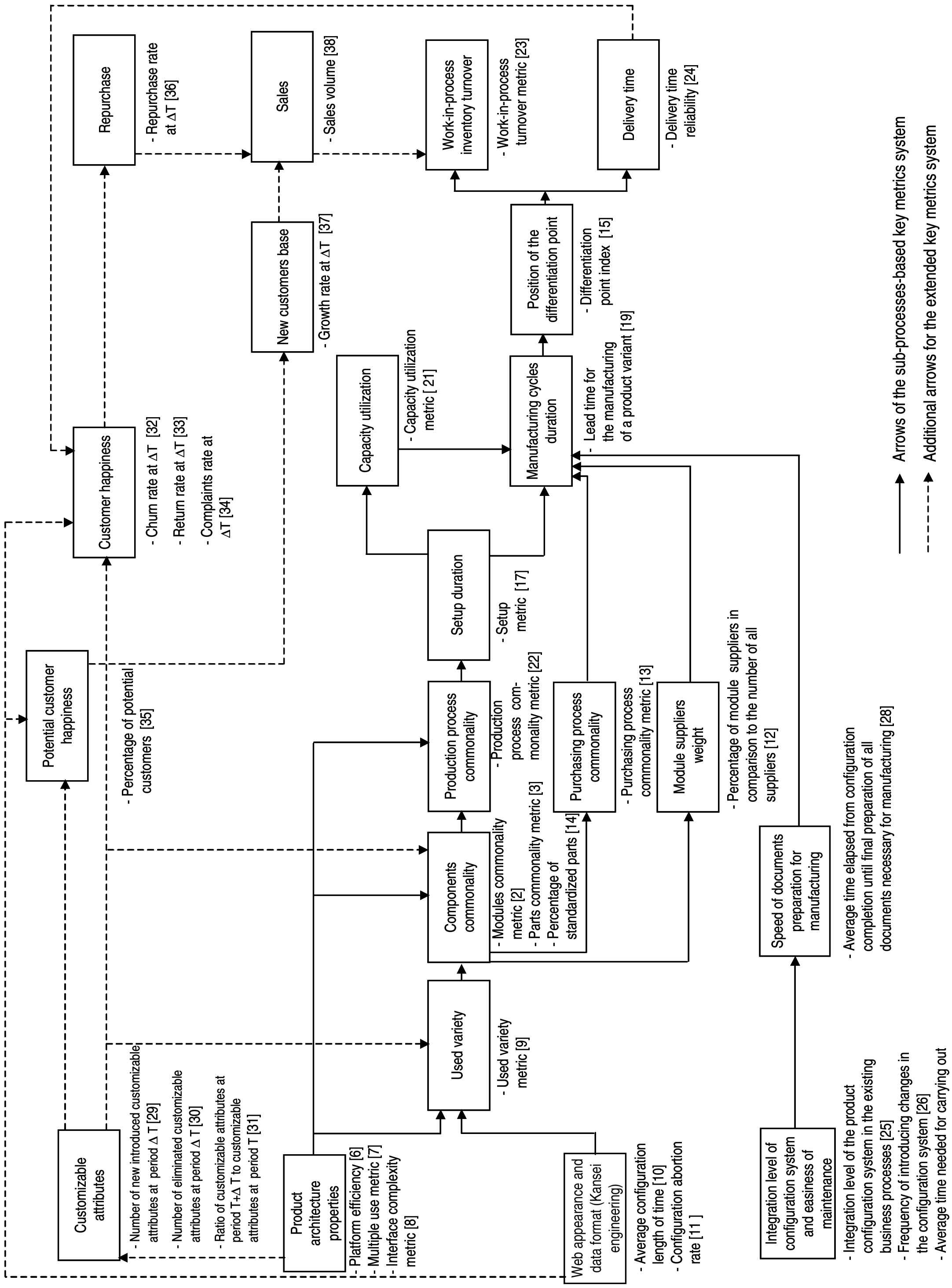


Figure 6: Extended key metrics system for variety steering in mass customization

Offering a large amount of configurable alternatives for the attributes contributing to the objective needs raises customers' happiness because, with each additional alternative, the likelihood that the customers find an optimal choice increases. The second unit (S) is capable of recognizing which product attributes confuse customers or are over-engineered. A large amount of alternatives for these attributes will only increase confusion and regret because the customers do not require customization of these attributes. The attributes provided by (S) share one common characteristic to be appreciated with the same values by most customers. However, these attributes could have high, middle or low customer values. The attributes with high customer values should be kept in the production program. But a free customization is not necessary. The attributes with middle and low customer values should be carefully examined by trading off customers' willingness to pay and the corresponding costs to be able to decide whether it is worthwhile to serialize or to eliminate these attributes.

Before adding the new customizable attributes proposed by (O) to the production program, the mass customizer should carry out a first test consisting of checking out whether these attributes can be produced by means of the existing production processes. If some attributes require new investments, then the mass customizer has to consider the outsourcing alternative and if there are suppliers in the supply chain being able to carry out the corresponding customizing process or deliver the required material, components or modules. The arising costs through this alternative should be scrutinized. If new investments are necessary, then this is a strategic decision which must be economically examined by the upper management. This case, that is, when decisions related to variety require new investments, will not be taken further into account because we only consider the case when variety decisions are achievable on the basis of available investments. The second test will be achieved with the help of the developed key metrics system. We propose to divide this system in 4 zones as shown in Figure 7 which is based on the extended key metrics system of Figure 6. *Zone I* consists of the performance parameter: customizable attributes. *Zone II* is composed of the performance parameters related to the product architecture and configuration system. *Zone III* comprises the key metrics related to the evaluation of the variety-driven internal complexity. *Zone IV* is composed of the performance parameters considering customers and sales.

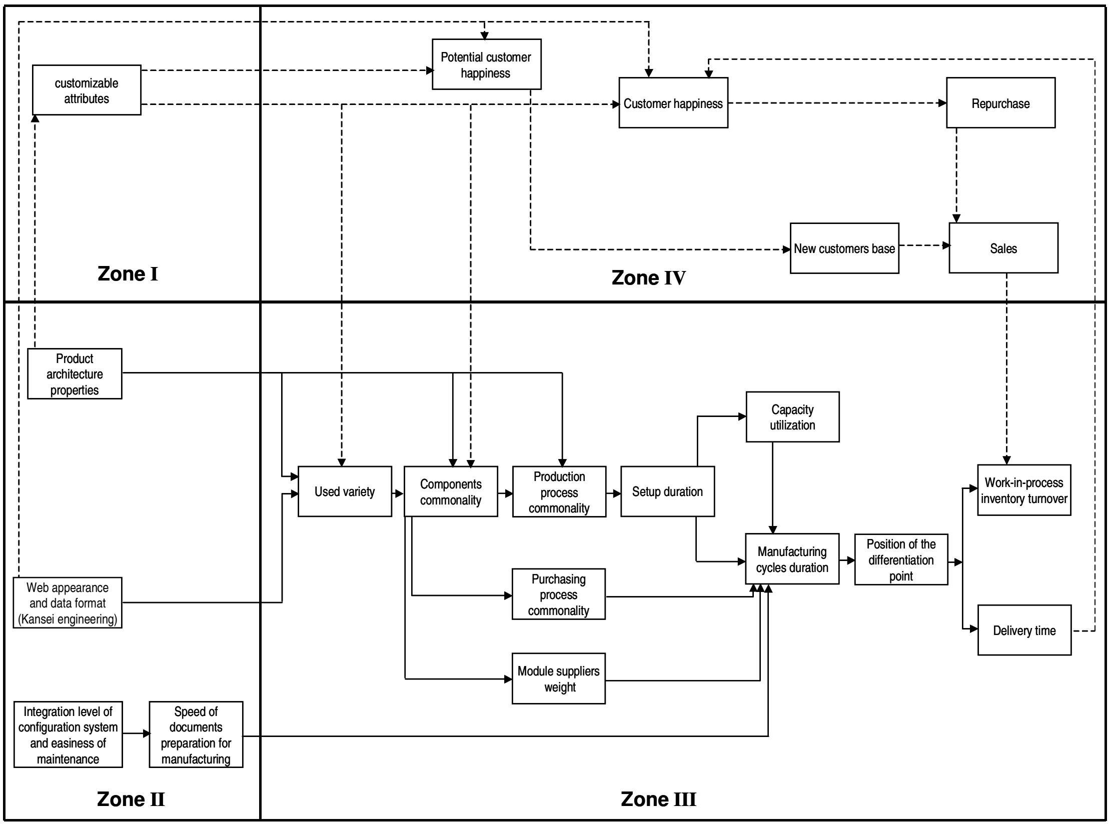


Figure 7: Suitable key metrics arrangement for variety steering

At a point in time T the decision concerning the introduction of the attributes proposed by (O) and/or the serialization or elimination of the attributes proposed by (S) affect the key metrics of *Zone I* and *Zone III*. The key metrics of *Zone III* provide the basis for the second test. The key metrics' values examination will provide an idea to what extent the internal complexity changes. When complexity considerably increases, one or some attributes have to be abandoned. In order to determine which attributes should be eliminated, we recommend classifying them according to the customer values. The attribute with the lowest mean value among all customers can be eliminated, then the resulting impact on the key metrics of *Zone III* has to be analyzed. If the complexity is still high then the mass customizer has to carry out a second iteration and eliminate the next attribute with the next lowest mean customer value. The iterations continue until the resulting complexity is evaluated as acceptable. Furthermore, the values taken by the key metrics of *Zone III* strongly depend on those of *Zone II* are considered to be less sensitive than the other key metrics because their values more or less depend on long term decisions. So it is conceivable that the successive elimination of many attributes does not decrease the internal complexity. It would be necessary, for example, to improve the integration level of the configuration system into the business processes or to enhance the product architecture, which is generally associated with investment costs.

The attributes retained after the complexity test carried out with the help of the key metrics of *Zone III* are the subject of a third test. The purpose of this test is to compare the cost positions of the mass customizer to those of the competitors regarding these attributes. It is not suitable to compare the cost positions of each attribute with the corresponding one of the competitor. Therefore, we recommend comparing the cost positions of a bundle of attributes with those of competitors because some attributes in the bundle can have a bad cost position, whereas the total cost of the bundle is advantageous. The attributes succeeding all the three described tests can be introduced to the production program. Furthermore, the importance of the key metrics of *Zone IV* consists of pointing out how in the period of time (ΔT) following the introduction of the new end product variants, the customer reacts to this new variety. Therefore, it is important to switch off all the effects of other factors on these metrics to analyze only the effects due to variety. If customer happiness decreases, this suggests that customers do not appreciate the introduced variety. Therefore, the units (O) and (S) should be revised or the web appearance and data format of the configuration system have to be improved.

This application for variety steering in mass customization shows how it is possible to manage internal complexity, while keeping a maximal orientation on the customer needs. From the key metrics „customer happiness“ and „potential customer happiness“, it is possible to draw some conclusions as to whether the mass customizer moves towards fulfilling the objective or only the subjective needs of the customers. For example, bad values for „customer happiness“ and „potential customer happiness“ would suggest that the offered variety to a great extent corresponds to the subjective needs which rather confuse the customers and only contribute to a satisfaction which is sub-optimal.

4 Constraints and Requirements

By developing the key metrics system we want to keep the model as general as possible. Therefore, we concentrate on defining performance parameters to which key metrics can be ex post assigned. The performance parameters should be considered as aggregates of several key metrics. But from one practical case to another, the relevant key metrics can be quite different. For this reason, we do not claim that the key metrics are definite and do not require any adaptation to the requirements of a particular case. The mass customizer who wants to apply this model has to consider the key metrics as a suggestion based on a comprehensive literature research. But we are convinced that the performance parameters can fit the majority of cases in mass customization.

The problem arising when distinguishing between the objective and the subjective customer needs is demanding and challenging. Dealing with this problem only by means of a simple tool such as a key metrics system is advantageous but can certainly not provide the optimal solution. That is why we consider our work to be a first solution approach and further work has to be done in order to develop concepts capable of solving more aspects of this problem. In order to relate variety to customers, we use the model of Desmeules (2002) associating the amount of variety with customer happiness. Giving accurate values for the corresponding parameters is not usually easy, especially when all other impacts on happiness except for those of variety should be switched off.

As described above, we divide the key metrics system into 4 zones. We notice that it is not possible to compute the key metrics' values of all defined zones at the same point in time. The impacts of variety steering decisions on the fulfillment level of the objective needs can be only ex post assessed after introducing the new product variants. It would be more advantageous if it were possible to simulate the impacts of variety steering decisions on the key metrics' values related to customer happiness before adding the new variants. So it would be already possible in the variety decisions' phase to predict whether the variety steering decisions would improve the orientation of the mass customizer on the objective needs.

Furthermore, in order to benefit from the potentials of the key metrics system it will be necessary to define target values. Key metrics will have no relevance, if it is not possible to compare them with predefined targets. So we suggest that the mass customizer intending to use the key metrics system benchmarks the performances with other companies which are active in the same or different fields. It is also conceivable to create a website where several mass customizers put their data online to ensure a continuous key metrics-based benchmarking of their performances regarding variety steering.

5 Conclusion

The main goal of this paper is to provide a key metrics system for variety steering in mass customization. We make the difference between variety management and variety steering concepts. Variety management aims at increasing components and process commonality levels during company operations by applying such concepts like platform and modules/systems strategies. Variety steering concepts deal with the external variety which is apparent and offered to the customers. We point out that variety steering should not be based on vague decisions. Customer orientation means in no way to offer a huge amount of variants because customers do not honor large assortments per se. They want to receive only the configuration corresponding to their requirements. Therefore, we propose a model to enable better understanding of the variety problems in mass customization. We distinguish between objective and subjective customer needs. The subjective needs are the individually realized and articulated requirements, whereas the objective needs are the real ones perceived by a fictive neutral perspective. With the help of this model we explain the shortcomings of the existing variety steering concepts such as e.g. Pareto analysis, contribution margin accounting and activity based costing aiming only at reducing variety. The proposed model shows that there are discrepancies between the objective needs, the subjective needs and the offered variety. We conclude that, as opposed to existing variety steering methods, an efficient variety steering concept has to be able to add good variety corresponding to the objective needs and eliminate bad variety, which either is over-engineered or corresponds solely to the subjective needs.

In order to develop a tool to enable us to solve the variety steering problem in mass customization we opt for a key metrics system solution. In order to achieve this goal we define the main sub-processes influenced by variety steering decisions. On the basis of the sub-processes analysis, we determine the most relevant performance parameters capable of capturing the impacts of variety. These performance parameters are then presented in a comprehensive model showing the interrelations between them. We assign to the performance parameters the corresponding relevant key metrics. This key metrics system shows that variety steering decisions are not only constricted by the product architecture but also by the characteristics of the configuration system and its integration in the existing business processes. However, the suggested sub-processes based key metrics system does not enable us to solve the problems arising when distinguishing between the objective and subjective needs of the customers. We conclude that this key metrics system should be extended. We propose some solutions capable of mitigating the communication problems emerging between the mass customizer and the customer such as Kansei engineering, and the key value attributes concept. However, these two concepts are not able to deal with the difficulties encountered when the customers do not know their real needs. This complex problem presents an issue for further research. The extended key metrics system takes into account the customer perspective and includes two important performance parameters, namely customer and potential customer happiness. The extended key metrics system serves to develop an application for variety steering in mass customization. We explain how to proceed in order to evaluate the impacts of variety steering decisions from customers' and companies' perspectives. However, we do not determine the characteristics of the hypothetical units (O) and (S). This constitutes an issue for further research in mass customization. We are also convinced that the data arising during the interaction between customers and the configuration system can be explored in order to define the characteristics of these units.

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Appendix

Performance Parameters	Key Metrics
Product Architecture Properties	[1] $\text{Platform efficiency metric} = \frac{\text{R \& D time for derivative product}}{\text{R \& D time for Platform version}}$ Source: Meyer/Lehnerd, 1997
	[2] $E_v = \frac{N_v}{N_{mt}}$ E_v : Multiple use metric N_v : Number of product variants required by customers N_{mt} : Total number of modules required to build up all the product variants Source: Ericsson/Erixon, 1999, p. 127
	[3] $I_c = \frac{\sum_{i=1}^{N_m - 1} T_i}{A_t}$ I_c : Interface complexity metric N_m : Number of modules in one product variant T_i : Assembly time for one interface A_t : ideal assembly operation time Source: Ericsson/Erixon, 1999, p. 114
Web Appearance and Data Format	[4] $CT = \frac{\sum_{i=1}^{N} CT_i}{N}$ CT : average configuration length of time CT_i : time needed from one customer to fulfil oneconfiguration N : number of fulfilled configurations
	[5] $\text{Configuration abortion rate} = \frac{\text{Number of aborted configuration processes}}{\text{Number of log - ins}}$
Used Variety	[6] $\text{Used variety metric} = \frac{\text{Number of perceived variants}}{\text{Number of all possible variants}}$ $0 < UVM \le 1$ Source: Piller, 2002, p. 15
Components commonality	[7] $\text{Modules commonality metric} = \frac{\text{Number of common modules}}{\text{Number of all modules}}$
	[8] $\text{Parts commonality metric} = \frac{\text{Number of common parts}}{\text{Number of all parts}}$
	[9] Percentage of standardized parts (within a part category) $= \frac{\text{Number of standardized parts}}{\text{Number of all parts}} \times 100$
Production Process Commonality	[10] $\text{Production process commonality metric} = \frac{\text{Number of common production processes}}{\text{Number of all production processes}}$
Purchasing Process Commonality	[11] Purchasing process commonality metric (within a part category) $= \frac{\text{Number of standardized purchasing processes}}{\text{Number of all purchasing processes}}$
Module Suppliers Weight	[12] Percentage of module suppliers in comparison to the number of all suppliers $= \frac{\text{Number of module suppliers}}{\text{Number of all suppliers}} \times 100$
Setup Duration	[13] $SM = \frac{\sum_{i=1}^{n} v_i t_i}{\sum_{j=1}^{v_n} T_j}$ $0 < SM < 1$ SM : Setup metric v_i : Number of different products exciting process i n : Number of processes v_n : Final number of varieties offered t_i : Average time needed for a setup at process i T_j : Average total lead time needed for the manfacturing of j^{th} product Source: Martin/Ishii, 1996, p. 6 (modified)

Capacity Utilization	[14] $\text{Capacity utilization metric} = \dfrac{\text{Processing time}}{\text{Processing time} + \text{idle time}}$ Source: Mueller, 2001, p. 73
Manufacturing Cycles Duration	$T_j = \dfrac{N_p T_a}{N_m} + T_{nva} + \dfrac{(N_m + N_s) - 1}{T_i}$ [15] T_j : Lead time for the manufacturing of product variant j N_p : Number of all parts assembled in modules in the plant N_m : Number of manufactured modules in one average product variant N_s : Number of supplies modules in one average product variant T_a : Average assembly time for one part T_{nva} : Average time for non value adding activities T_i : Average assembly time for interfaces between modules Source: Ericsson/Erixon 1999, p. 118 (modified) $T_{nva} = \text{move time} + \text{wait time} + \text{inspection time} + \text{setup time}$ Source: Maskell, 1991, p. 258
Position of the Differentiation Point	$DI = \dfrac{\sum_{i=1}^{n} d_i\, v_i\, a_i}{n\, d_1\, v_n \sum_{i=1}^{n} a_i}$ [16] DI : Differentiation point index v_i : Number of different products exciting process i n : Number of processes v_n : Final number of varieties offered d_i : Average throughput time from process i to sale d_1 : Average throughput time from beginning of production to sale a_i : Value added at process i Source: Martin/Ishii, 1996, p. 6
Work-in-Process Turnover	[17] $\text{Work-in-process turnover} = \dfrac{\text{Total sales}}{\text{Value of the work-in-process inventory}}$ Source: Pine, 1993, p. 112
Delivery Time	[18] $\text{Delivery time reliability (DR)} = \dfrac{\text{Agreed delivery time}}{\text{Real delivery time}}$
Integration level of the Configuration System and Easiness of Maintenance	[19] $IL = \dfrac{NIP}{NP}$ IL : Integration level of the configuration system in the existing business processes NIP : Number of business processes integrated in the configuration system NP : Number of all business processes
	$FIC(\Delta T) = \dfrac{NC(\Delta T)}{\Delta T}$ [20] $FIC(\Delta T)$: Frequency of introducing changes in the configuration system at a period ΔT $NC(\Delta T)$: Number of changes and data base up dates at a period ΔT ΔT : Period of time
	$AT_c = \dfrac{\sum_{i=1}^{nc} T_{c_i}}{nc}$ [21] AT_c : Average time for carrying out one change in the product configuration system T_{c_i} : Time required for change i nc : Total number of changes introduced in the configuration system
Speed of Documents Preparation for Manufacturing	$AT_{(cc \rightarrow dp)} = \dfrac{\sum_{i=1}^{no} T_{(cc \rightarrow dp)i}}{no}$ [22] $AT_{(cc \rightarrow dp)}$: Average time elapsed from configuration until documents preparation for manufacturing $T_{(cc \rightarrow dp)i}$: Time elapsed from the completion of configuration i until documents preparation no : Number of all orders
Customizable Attributes	[23] Number of new introduced customizable attributes at period ΔT : $N_n(\Delta T)$
	[24] Number of eliminated customizable attributes at period ΔT : $N_o(\Delta T)$

	[25] $R(T+\Delta T, T) = \frac{\text{Number of customizable attributes at T} + \Delta\text{T}}{\text{Number of customizable attributes at T}} = \frac{N(T) + N_n(\Delta T) - N_0(\Delta T)}{N(T)}$ $R(T+\Delta T, T)$: Ratio of customizable attributes at period T + ΔT to customizable attributes at period T $N(T)$: Number of customizable attributes at period T
Potential Customer Happiness	[26] $\text{Percentage of potential customers (PC)} = \frac{\text{number of potential customers}}{\text{number of customers} + \text{number of potential customers}} \times 100$
Customer Happiness	[27] $\text{Customers churn rate at } \Delta\text{T } (CCR(\Delta T)) = \frac{NOLC(\Delta T)}{NOC(T) + NONC(\Delta T) - NOLC(\Delta T)}$ $NOLC(\Delta T)$: Number of lost customers at ΔT $NOC(T)$: Number of customers at T $NONC(\Delta T)$: Number of new customers at ΔT Source: Sterne, 2002, p. 146
	[28] $\text{Return rate at } \Delta\text{T } (RR(\Delta T)) = \frac{\text{Number of returned products}}{\text{Number of delivered products}}$ Source: Piller, 2002, p. 16
	[29] $\text{Complaints rate at } \Delta\text{T } (CR(\Delta T)) = \frac{\text{Number of complaints } (\Delta\text{T})}{\text{Number of deliveries } (\Delta\text{T})}$
New Customers Base	[30] $\text{Growth rate at } \Delta\text{T } (GR(\Delta T)) = \frac{NONC(\Delta\text{T})}{NOC(T)}$ Source: Sterne, 2002, p. 146
Repurchase	[31] $\text{Repurchase rate at } \Delta\text{T } (R(\Delta T)) = \frac{\text{Repurchase through extisting customers } (\Delta\text{T})}{\text{New customers } (\Delta\text{T})}$ Source: Piller, 2002, p. 15
Sales	[32] $\text{Sales volume } (\Delta\text{T}) = \text{number of sold units } (\Delta\text{T})$